Some Design Features of the N-1 Carrier Telephone System

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Introduction

The economics which result from sharing the cost of line facilities among a number of channels, and the transmission advantages of carrier circuits (in the form of high speed transmission which minimizes delay and echo effects, low net loss and high quality), have combined to bring about a revolution in long distance telephony. Whereas fifteen years ago only 8% of the toll circuit mileage of the Bell System was furnished by carrier, today carrier circuits comprise about two-thirds of the total mileage. The minimum distance, however, for which carrier can economically replace voice frequency transmission has been limited by the cost of the carrier equipment, the cost of line treatment, the expense of installation and associated job engineering, and the maintenance effort required. As a result, the shorter toll circuits, relatively large in number though not in circuit mileage, have continued to operate at voice frequency. The newly developed Type N-1 Carrier Telephone System is aimed primarily at expanding the application for carrier into this field of short haul service. As explained elsewhere[1], it is designed to obtain the advantages of carrier for toll and exchange cable circuits for lengths a small fraction of the previous economic minimum.

Many system and circuit features contribute to this end. There are 12 channels per system with 8 kc spacing between carriers. The carrier and both sidebands are transmitted. All of the pairs in a single cable can be used for Type N without special cable treatment. Repeaters are spaced 6 to 8 miles apart depending upon the gauge of the cable conductors. Power is fed over the cable pairs to two out of every three repeaters, which can be pole mounted. Different frequency bands on different pairs in the same cable are used for opposite directions of transmission, 44–140 kc in one direction, and 164–260 kc in the other. The frequency bands are interchanged and inverted at each repeater to avoid important types of crosstalk, and to provide automatic equalization of attenuation slope. Compandors, built into the channel terminals, raise the lower speech volumes prior to transmission and restore them after reception, thereby minimizing the severity of crosstalk and noise problems on the line and in the terminals. An out-of-band signaling channel immediately above the speech band is provided by built-in equipment.

[1] "The Type N-1 Carrier Telephone System: Objectives and Transmission Features," R. S. Caruthers, January 1951 issue of this *Journal*.

Important as these new system and circuit techniques are, they could not in themselves accomplish the objectives of small manufacturing cost, minimum engineering by the customer, ease of installation, and substantial dimunition of maintenance effort. Contributing in large measure to the overall success of the Type N System are new and interdependent features in the components and equipment, whicb in combination represent a complete transformation from the past. Miniaturized components and improved assembly techniques yield large reductions in size and weight. Unitized construction with packaged sub-assemblies not only simplifies installation, but greatly facilitates the finding and correction of trouble, permitting shipment of defective units to a central point for overhauling and thereby making it possible to maintain the working equipment with plant personnel not highly trained in carrier techniques. A furtber contribution to ease of maintenance has been made in various instances by extension of the life of components in order to avoid the necessity for frequent replacement. These and other features of the Type N equipment are described in this paper, which discusses first the components and their characteristics, and then the design of the equipment assembly.

Resistors, Capacitors, and Inductors

The circuit arrangements of the N-1 System have been designed with adequate margins to permit generous use of the low cost, small capacitors, resistors and potentiometers in commercial manufacture. Deposited carbon resistors find application where high circuit precision is necessary, while vitreous enamel coated resistors are used where higher power dissipation is required.

Capacitances of several microfarads or more must be compressed into a small volume for miniaturized equipment. Aluminum electrolytic capacitors, which have been used for this purpose, have limited life due to the susceptibility of aluminum to corrosion by common reagents and contaminants. In the Type N System, high capacity, long life tantalum electrolytic capacitors of both polar and non-polar types find their first Bell System application[2]. These tantalum capacitors are considerably smaller than the aluminum type. Two types of tantalum capacitors are used. In the sintered type the anode is made by pressing powdered tantalum into a compact shape and then sintering in a vacuum furnace to weld tbe powder particles. This creates a porous mass in which a relatively large surface area is exposed for oxide film formation, and hence a large capacitance per unit volume of material is obtained. In the foil type, two foil electrodes are wound in the conventional manner into a cylindrical unit with a paper separator. Size

[2] "Tantalum Electrolytic Capacitors," M. Whitehead, *Bell Laboratories Record*, October 1950.

reduction is realized for this type since the high tensile strength of tantalum permits manufacture using very thin foil. From the measured stability of the tantalum oxide film, and from the known immunity of tantalum to attack by acid reagents, it is concluded that the life of a tantalum electrolytic capacitor will be several times that of the corresponding aluminum electrolytic capacitor. Three capacitance ratings are in production for use in the

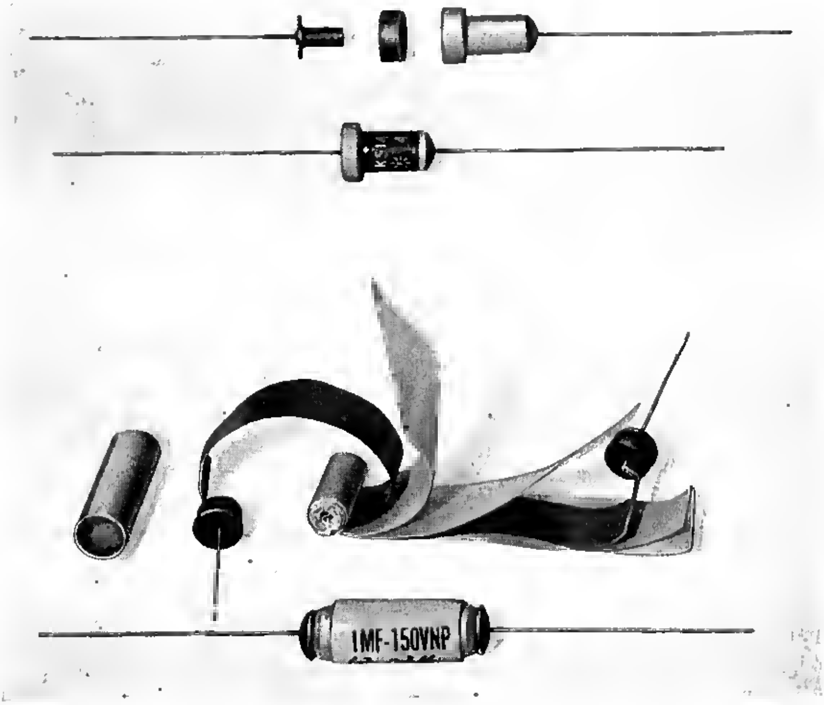

Fig. 1—Tantalum capacitors. Upper: Sintered type, 4 mf/60 volt polar; Lower: Foil type, 1 mf/150 volt nonpolar.

N-1 System: one of the sintered construction, 4 mf/60 volts polar; and two of the foil construction, 1 mf/150 volts polar and 1 mf/150 volts non-polar. Examples of these capacitors are illustrated in Fig. 1.

The inductors employed in the Type N System are of several types. Two toroidal type inductors, each wound over a small low cost molyhdenum permalloy dust core, are used in the voice frequency filters and in hattery supply leads. Individually mounted duo-lateral wound inductors find application in interstage networks. Two duo-lateral type inductors wound on a common molded phenolic core tuhe are used in carrier frequency filters.

Adjustable magnetic cores are used with these latter inductors to facilitate precise tuning with associated capacitors. The mutual inductance inherent between inductors wound in this manner is desired in the case of the channel band filters. In the high and low pass carrier frequency filters, where the effect of mutual inductance is detrimental to filter performance, a small inexpensive inductor is added to annul this mutual. This inductor comprises

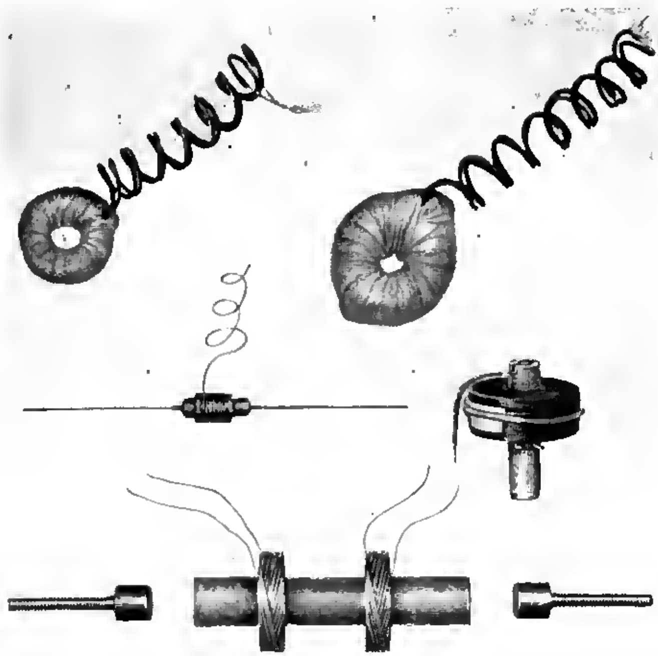

Fig. 2—Various types of inductors used in the N-1 carrier telephone system.

a parallel pair duo-lateral winding on a solenoidal iron dust core. Figure 2 illustrates some of the inductors used in the system.

Transformers

In the transformer designs used in the system both miniaturization and low cost are attained through the use of few parts and common parts wherever possible, improved manufacturing techniques allowing the use of much finer wire than heretofore practical, and multiple-winding methods for all designs. For the voice and signaling circuit transformers, where there is no superimposed direct current flowing through the windings, the core structure consists of interleaved "E" and "I" permalloy laminations. For the

case where superimposed direct current is flowing in the windings, the core structure is formed by a wrap-around assembly of several strips of permal-

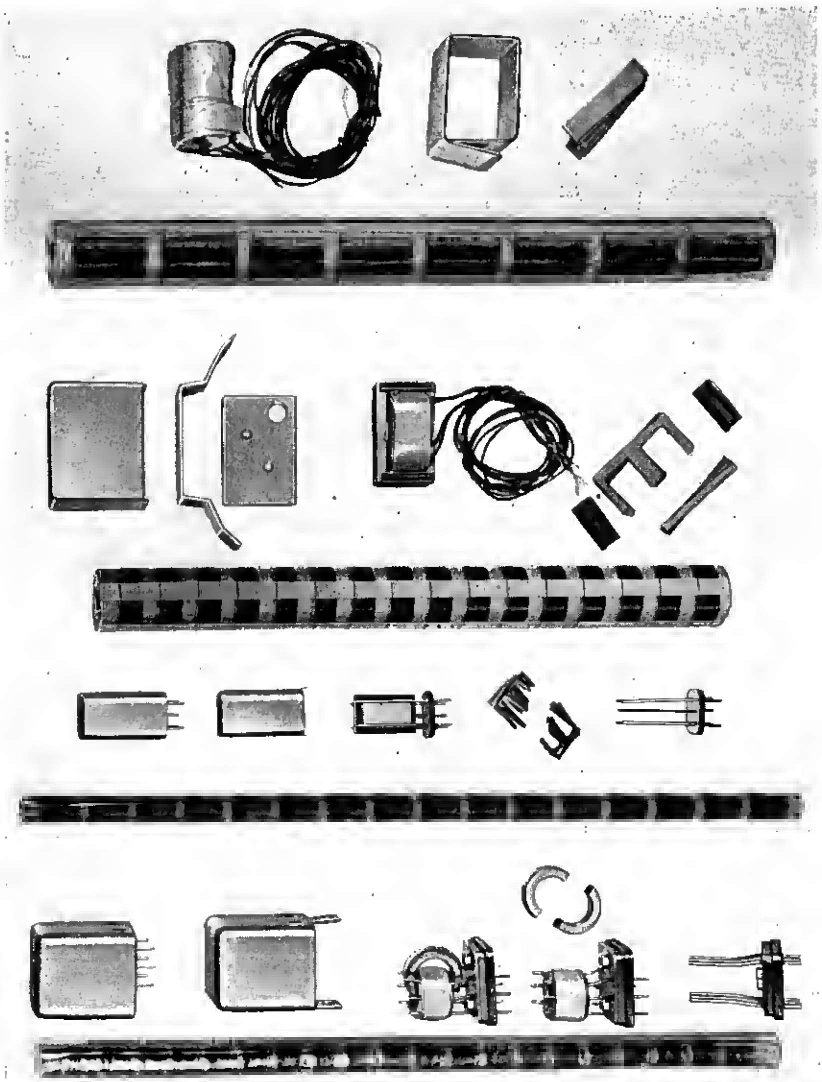

Fig. 3—Voice, signaling and carrier frequency transformers.

loy tape and a stack-up of "I" laminations. One of the signaling frequency transformers is an adaptation of the type used in hearing aids which was modified to make it suitable for Bell System use.

The carrier frequency transformers also exemplify small size. They are alike in structure, employing acetate filled windings assembled over small toroidal molybdenum permalloy dust cores which are broken in half to accept the winding assembly and cemented together again. The winding and core assembly is supported from the terminals which are molded into the cover plate. This construction method further simplifies fabrication by eliminating the need of intermediate lead wires from the winding assembly, the fine wire of the windings being connected directly to the transformer terminals.

All transformers are housed in drawn aluminum cases and are equipped with threaded metal inserts in the covers for mounting. Construction features of the various transformers are shown in Fig. 3.

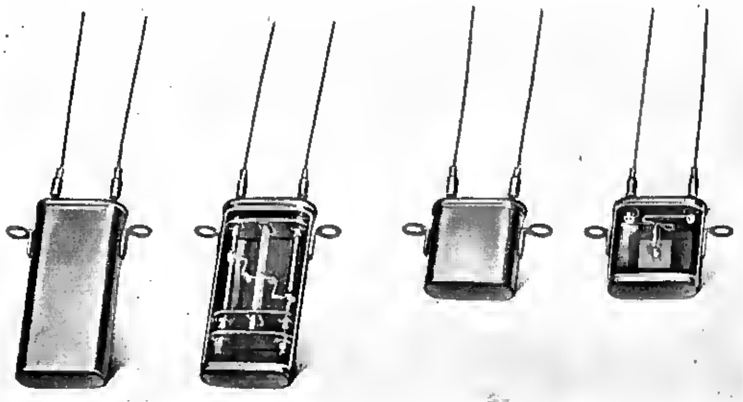

Fig. 4—Quartz crystal units used for carrier frequency oscillator control.

Crystals

The 12-channel carrier frequencies required for the system are supplied by quartz-crystal controlled oscillators covering the range of 168 kc to 256 kc in 8 kc steps. These crystals are $+5°$ X cut quartz plates operated in a fundamental extensional mode, with gold electrodes plated on the major surfaces, wire mounted and hermetically sealed in metal holders with mounting leads. The crystal used to control the 304 kc carrier supply oscillator for the group modulator is a DT quartz crystal plate operating in the shear mode, otherwise similar to the crystals for the channel frequencies. The two designs are shown in Fig. 4.

Varistors

Nearly eight hundred small germanium varistors are used as circuit elements in the two terminals of an N-1 system. Slightly more than half of this

number are used as single elements to perform such functions as vario-losser bias control, rectifier, channel demodulator, keyer for signaling frequency, voltage doubler in the signaling circuit and current divider in the expandor circuit. The remainder are assembled into three groups of care-

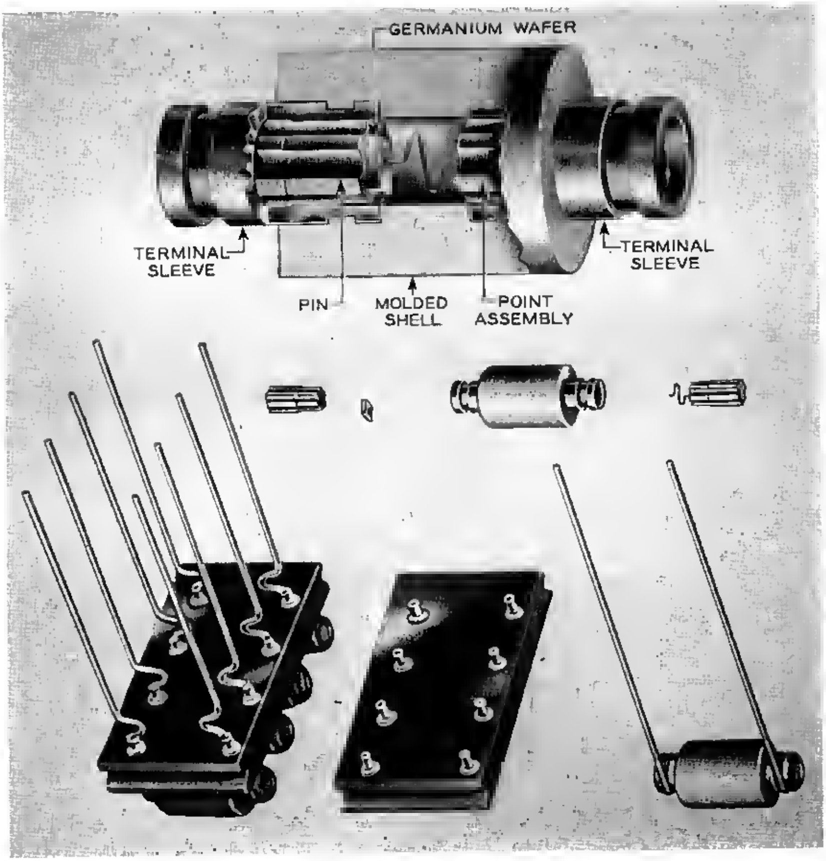

Fig. 5—Germanium varistors. Lower right: Germanium varistor unit with an exploded view directly above; Top: Magnified cross section of the same unit. The functional elements are a wafer of germanium which is soldered to the fluted pin at the left and the "S" shaped tungsten wire in the pin at the right. The rectifying junction produced under the tungsten point contact with the specially prepared germanium surface is the seat of the non-linear resistance characteristic. Lower left: Vario-losser assembly.

fully selected units, for use as the channel modulator, the compressor vario-losser and the expandor vario-losser respectively. The germanium varistor unit is shown at the lower right of Fig. 5.

The compandor vario-losser varistors are of special interest because of the important function they perform and the way in which the desired close

limit non-linear characteristic is obtained. At the left of Fig. 5 is a view of the compressor vario-losser assembly and extending to the right the components from which it is constructed. Similar construction is used for the expandor and channel modulator units. The vario-losser units function by virtue of the fact that their a-c impedance can be varied and closely controlled by a d-c bias. Consequently, when made a part of a suitable network and controlled by a d-c bias proportional to the signal level, the compressor, which comprises four varistor elements, can be made to increase its attenuation as the signal increases; while in a different network, the expandor, which comprises six varistor elements, can be made to decrease its attenuation with increasing signal. The close degree to which the compressor and expandor characteristics must complement each other makes it necessary to use varistor elements that are very precisely controlled as to their a-c impedance at specific values of bias current. This is accomplished by careful selection of elements which comprise only a fraction of the total distribution of characteristics produced and then grouping these selected units into assemblies as illustrated. These selected groups must then pass transmission requirements which are directly related to the compandor performance.

The channel modulator is also composed of selected germanium varistors but, unlike the vario-lossers, the modulators do not all have to be substantially alike. It is sufficient that the four elements comprising any one modulator be alike to control the carrier leak. One modulator may then differ considerably from another in impedance.

Copper oxide instead of germanium varistors are used in the group modulators at terminals and repeaters because their lower impedance level and somewhat lower noise figure give better performance in these circuits.

Thermistors

A thermistor, which introduces a large change of resistance with temperature, is used to regulate the gain of the repeaters and group amplifiers. The thermistor element is a tiny pellet of semi-conducting oxides which is equipped with lead wires, a glass coating and an insulated heater. This whole assemblage, which is less than a tenth of an inch in diameter, is covered with a bright gold coating and enclosed in an evacuated glass tube to reduce heat losses. A network consisting of a thermistor disc and two wire wound resistors, and tailor-made on the basis of precision measurements on the individual thermistor and heater, is included in the assembly to serve as a contactless thermostat for the power sensitive thermistor pellet so that the resistance of the latter is wholly under the control of transmission currents. The thermostat network also serves to adjust the pellet to standard characteristics, thus avoiding impracticable close tolerances on the basic dimensions and heat treatment processes during manu-

facture. The complete thermistor illustrated in Fig. 6 has less than one-third the volume of the corresponding thermistor used in the earlier K2 carrier system and as a result of design refinements will operate on less transmission power.

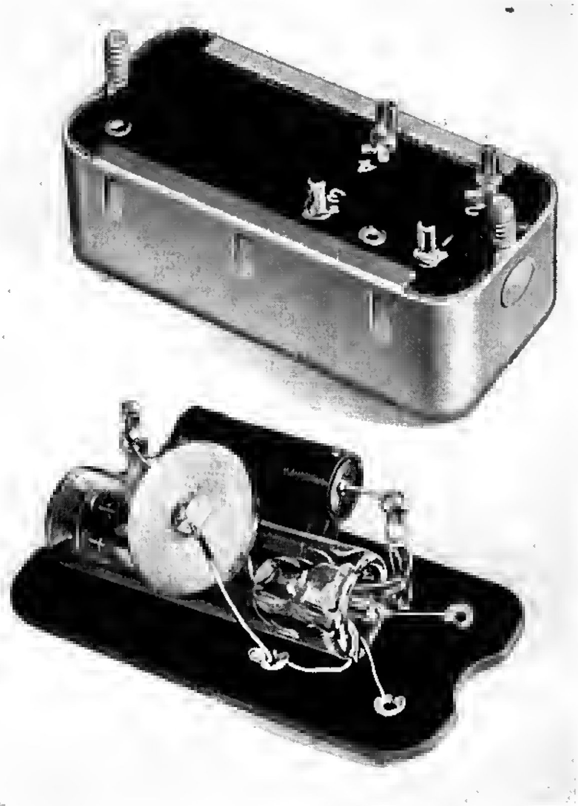

Fig. 6—Thermistor assembly used for gain regulation of repeater and group amplifiers

Filters and Equalizers

Filter and equalizer assemblies required in any system usually are the largest apparatus items and they vary considerably in size due to the differences in the type and number of circuit components needed to provide the desired performance characteristics. Although smaller components shrink the dimensions of these assemblies correspondingly, they are still incompatible with the dimensions of other apparatus items. It was decided, after study of the different circuit configurations and circuit elements needed for the N-1 System, to divide up the more complicated networks for as-

sembly into several units which could be connected together in the equipment assemblies. The more complicated filters and equalizers thus are comprised of two or more such units. Except for the signaling frequency filter the unit assemblies for all filters and equalizers in the system have the same housing and the same mounting facilities. This division of filters and equalizers into combinations of externally identical units permits more efficient

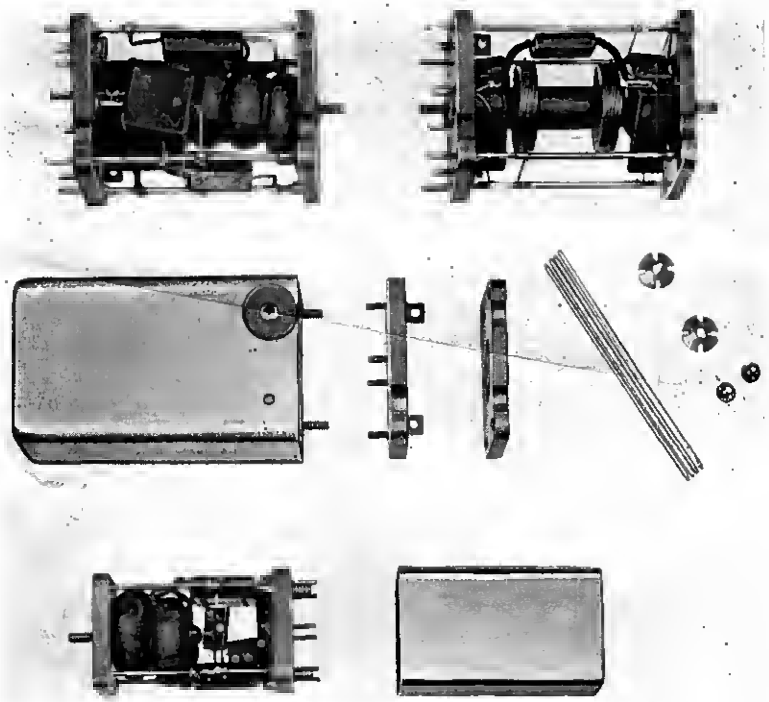

Fig. 7—Filter units. Upper left: Voice frequency unit; Upper right: Carrier frequency Unit; Center: Common parts, voice and carrier frequency units; Lower: 3700-cycle signal frequency filter.

use of space in equipment assemblies and is instrumental in lower manufacturing costs by utilization of common assembly details.

The unit assembly details consist of a drawn aluminum shield can equipped with mounting lugs and a cage type framework comprising two molded phenol end plates held together by four corner rods which also serve as four of the eight available terminals in the terminal side end plate. In the carrier frequency units, two duo-lateral type inductors wound on a common phenolic core tube are held in place by means of keyed recesses in the end plates. A threaded insert in each of the end plates supports the magnetic

tuning slug associated with each inductor. In the voice frequency units, which use toroidal molybdenum permalloy core inductors, these same threaded inserts accept the machine screw which supports the inductors. The associated capacitors and resistors support themselves from their leads after connection to the unit terminals. Carrier and voice frequency units are illustrated in Fig. 7.

Carrier Frequency Units

There are seventeen designs of carrier frequency filters: twelve channel band filters (each comprising two identical units) for use in the terminal equipment, a high-pass input filter (two different units) and a low-pass group modulator output filter (two different units) for use in High-Low repeaters, a low-pass input filter (one unit) and a broadband group modulator output filter (three different units) for use in Low-High repeaters, and a low-pass group modulator filter (one unit) for use at low group transmitting terminals.

The channel band filters are designed to utilize the mutual inductance between inductors, the bandwidth being a function of the coupling factor, and are schematically all alike. Channel separation by means of filters is required only at the receiving terminal. It was decided to do this separation only in the high frequency range. The use of one range required only 12 channel filter designs instead of 24, with resultant lower costs because of the doubling of the demand for each design. The upper frequency range was chosen: (1) because less mutual inductance is required and, since this causes the inductors to be farther apart, better control of the mutual inductance value can be realized; and (2) because it reduced capacitance values and resultant cost. The designs are such that the corresponding inductor windings are identical for all twelve channels, while the distance between windings, which controls the coupling factor, and the associated capacitors are different for each channel. Modifications made on standard duo-lateral type winding machines have made it possible to eliminate any adjustment of the coupling factor, which is held to $\frac{1}{2}\%$ limits by dimensional control only.

The high- and low-pass filters are of conventional configurations. The effect of mutual inductance in these circuits is to degrade performance by causing excessive distortion in passbands, displace attenuation peaks and limit otherwise realizable loss in the attenuating band. In order to utilize the same assembly methods as for the channel filters and to avoid the need for shielding schematically adjacent inductors, a small inductor is used to annul the unwanted mutual inductance. This inductor has two identical windings with nearly perfect coupling, so that the self inductance of each

winding and the parallel aiding inductance value are equal to the mutual inductance value to be annulled. If the loosely coupled windings of the main inductors are connected in series aiding, then interposing the windings of the annuling inductor in a series opposing fashion has the effect of adding nothing to the inductance of the main windings plus mutual but annuls the mutual in the equivalent T circuit. This is illustrated schematically in Fig. 8.

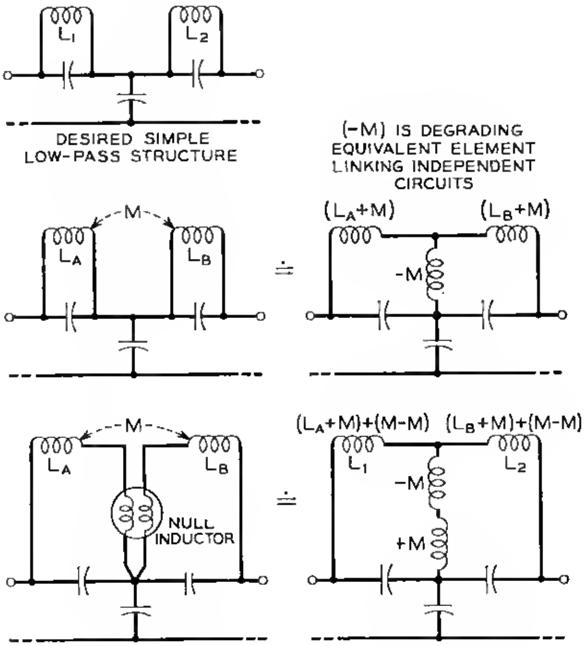

Fig. 8—Schematic illustrating the effect of introducing a mutual nulling inductor.

Three designs of carrier frequency equalizers are used in the system. Two of these provide the means for equalizing the slope of one cable span, amounting to approximately 14 db. The equalization is divided between the transmitting terminal (pre-equalization) and the receiving terminal (post-equalization) in order to minimize the effect of noise introduced along the cable. The third equalizer is designed to compensate for the accumulated small systematic distortions introduced by the cable spans and repeaters. This "deviation" equalizer is required only on the longer systems involving approximately 10 or more repeaters. Each of these three equalizers comprise 2 units similar in assembly to the carrier filters.

Voice Frequency Units

Two designs of voice frequency low-pass filters (one unit each) are used in the transmitter modulator input and the receiver demodulator output in each channel. The modulator filter limits the range of voice frequencies

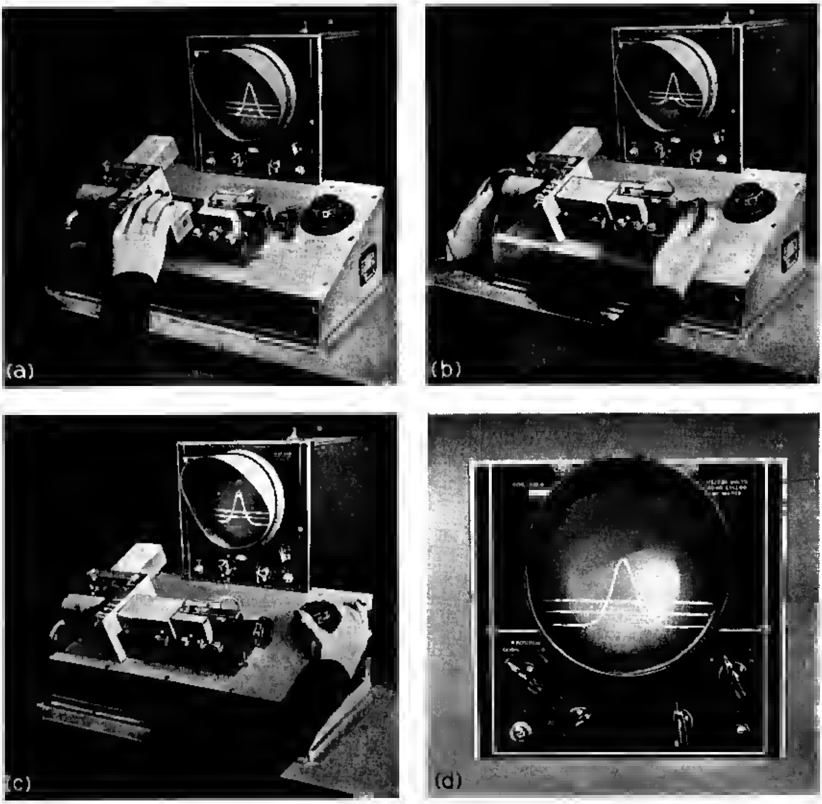

Fig. 9—(a) Operator inserting test filter in jig. Traces appearing on the cathode ray tube are the characteristic of a reference filter and two reference discrimination levels. The lower trace represents transmission in the test path, which circuit has not yet been completed. (b) Unadjusted filter characteristic appears on lower trace. (c) Adjustment completed, mid-band loss level being checked for limits. (d) Close-up of cathode ray tube which shows characteristic of filter under test coinciding with the characteristic of the reference filter.

to be modulated and provides suppression against 3700 cycle voice frequency interference into the signaling circuit. The receiving low-pass filter supplements the suppression provided by the channel filters to prevent inter-channel crosstalk and has an attenuation peak at 3700 cycles to prevent the signal tone from interfering with the message circuit. The pass-

band characteristics of these filters are shaped to provide the equalization needed in the individual message channels.

A narrow band filter centered at 3700 cycles selects the signal frequency at the receiving terminal and provides the suppression against all other frequencies needed to prevent false operation of the receiving signaling circuit. The design of this filter, which is also shown in Fig. 7, makes use of a cage type assembly similar to the other filter units but is somewhat smaller.

Unit Adjustment and Inspection

All carrier frequency filter and equalizer units are equipped with magnetic slugs to facilitate accurate adjustment of critical circuit resonances. In the case of the carrier frequency high- and low-pass filter units and the carrier frequency equalizer units, adjustments are made at attenuation peak frequencies. After adjustment, transmission measurements made at these same frequencies only are sufficient to determine satisfactory performance.

Adjustment and inspection of the channel filter units are accomplished by the use of a special test set which displays four traces on a cathode ray tube. One trace displays the transmission characteristic of the unit under test, the second trace displays the characteristic of an accurately adjusted reference filter unit and the two remaining traces display two reference discrimination levels. See Fig. 9. Blanking pulses are applied to the intensity grid of the cathode ray tube to blot out the traces at points corresponding to $\pm$ 4 kc from the mid-band frequency. The blotted out portion of the traces together with the discrimination level traces provide a coordinate system to establish bandwidth limits for inspection purposes. The magnetic slugs are adjusted so that the displayed characteristic of the filter unit under test is symmetrically located with respect to the displayed characteristic of the reference filter unit. If the adjusted characteristic of a filter unit passes through the coordinate established by the blanking pulses between the discrimination level traces it meets its requirements.

The electrical performance of the voice frequency low-pass filters and the 3700 cycle signal band filter is determined by transmission measurements at critical frequencies using standard test equipment.

Equipment

Equipment design of N-1 Carrier terminals and repeaters has been directed particularly towards small size and weight, low manufacturing cost, simplicity of engineering and installation, and ease of maintenance. Size and weight have been minimized by arranging the miniaturized components compactly in die cast aluminum frames of a size and shape to fully utilize the rack space available in depth as well as in breadth and height. This may be called "cubic" construction as contrasting with the "planar" con-

struction of conventional panels. This also facilitates manufacture as does a new method of mounting components of the "pigtail" type in parallel thermoplastic strips and the division of the equipment into subassemblies convenient for shop handling and so composed of circuit elements that the same subassemblies can be used in more than one part of the system. Maintenance is facilitated and service interruptions reduced to minimum length by arranging the units for interconnection by plugs and jacks so that a defective unit can readily be replaced by a spare and sent to a maintenance center equipped with adequate measuring equipment and manned by a technically trained and experienced personnel. Engineering and installation are facilitated by packaging the equipment so that the maximum possible portion of the assembly and wiring work is performed in the shop, and by avoiding engineered options.

The close packing of components in a relatively small space makes more serious the problems of wiring, shielding, heat dissipation, accessibility for inspection and maintenance, and major modifications.

Unitized Construction

This unit method of construction takes the form of conveniently sized plug-in assemblies. It makes efficient use of the full 10-inch depth available in the standard relay rack. The front of the unit carries the vacuum tubes adjusting potentiometers and test terminals which need to be accessible for routine system checking. Any space left over on the front panel is utilized by voice and carrier frequency transformers. Other components are compactly assembled inside the unit and are accessible only after the unit is removed from its frame mounting. The external connections of each unit terminate in a male connector which matches a female connector in the frame mounting. Both connector assemblies consist of a molded phenolic rectangular block equipped with 20 gold plated contacts. These assemblies are mounted by means of shoulder screws to give them a slight floating action which relieves the strain on contacts and wiring when the units are plugged in. After the units are plugged in they are secured to the frame mounting by means of quick-acting fasteners.

The plug-in method permits the testing of the units without expensive jack fields, and allows the removal of any unit in trouble and its replacement by a spare unit for immediate restoration of service. The defective unit can then be taken to a maintenance point where adequate tools and testing equipment are available for convenient repair work by experienced personnel. This is especially valuable in the N-1 system where a majority of the repeaters may be pole-mounted and many of the terminals located in unattended or partially attended offices. It will be valuable in other locations by eliminating repair work from a ladder. For the handling of units

along the cable route or shipping of units to and from a maintenance center, small light-weight fibre carrying cases are available.

To facilitate manufacture, the equipment units are subdivided into two or more subassemblies. The circuit is divided among these subassemblies in a way that is convenient for shop assembly and test. An additional advantage, in stocking for maintenance, is that certain of these subassemblies are common to several equipment units, thus reducing the investment in spare units. When the subassemblies are separated, the apparatus and associated wiring in each are readily accessible. Electrical connections between

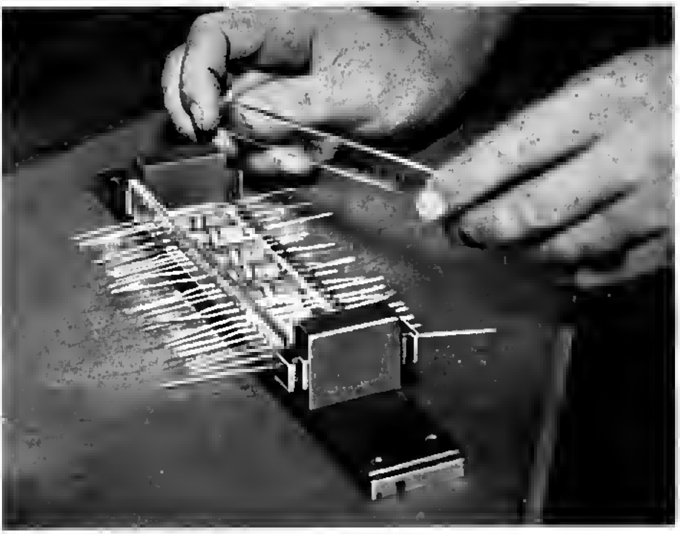

Fig. 10—Thermoplastic strips being positioned in assembly jig for pigtail components. The strips are precut to length from extruded "ribbons" and are stamped with equipment designations to identify the components.

subassemblies are accomplished by means of the same type of male and female connectors as are used between the complete unit and its frame mounting. For protection, particularly in handling, a slip-on can cover is provided for each equipment unit.

Mounting of Components

To meet the objective of low manufacturing costs, a simple and effective method of mounting tbe large number of pigtail components is essential. The method adopted arranges as many of these components as electrical requirements permit, on two parallel thermoplastic strips which in turn are mounted in the chassis. Simple assembly jigs, an example of which is shown in Fig. 10, position the strips and components so that the terminal

leads rest on the edges of the strips. The application of a slight pressure by a heated shoe imbeds in one operation the terminal leads of all the components of the assembly into the plastic material. The machine used for this purpose is shown in Fig. 11. Simultaneously with this operation, the terminal leads extending over the edges of the strips are sheared off to a length suitable to form terminals to which connections are made. If a component needs

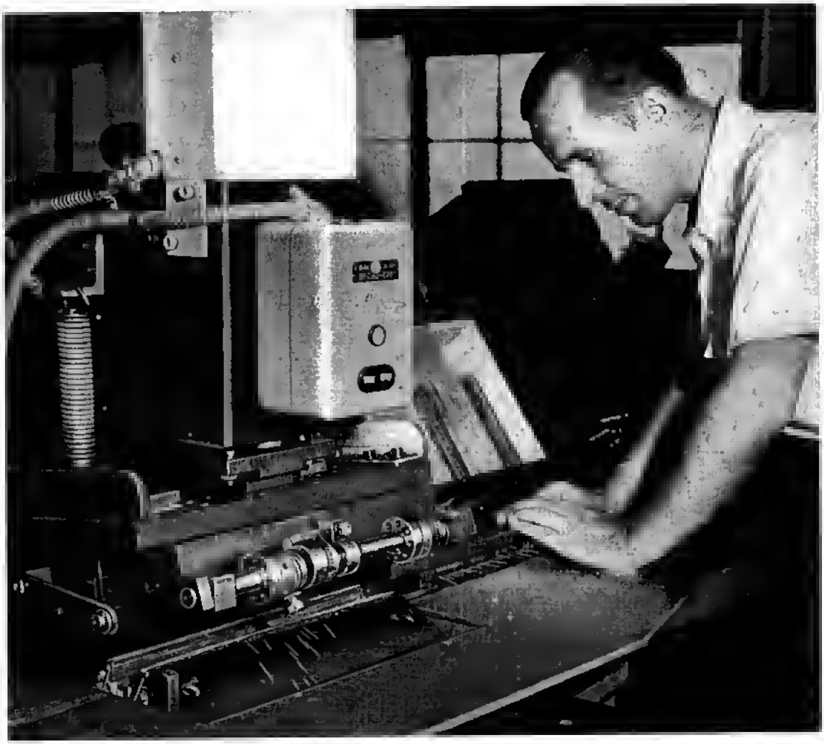

Fig. 11—Operator preparing to feed assembly jig to machine where heated shoe imbeds terminal leads of components into the thermoplastic strips. Cuttings from sheared off terminal leads may be seen below machine.

to be replaced this is readily done by applying heat to its leads with a soldering iron. To facilitate making the relatively large number of wiring connections to the pigtail components as well as to terminals of other components, pistol wrapped connections are used in many cases rather than the wrapping by hand with a pair of pliers. The electrically operated wiring pistol illustrated in Fig. 12 wraps the wire onto the terminal with high tension. The connections are then soldered.

Die Cast Chassis

In order that components of varying types and sizes may be mounted with their terminals in good position for wiring, the chassis construction must provide for a variety of mounting surfaces in various planes. Such chassis cannot be fabricated economically even in large quantities, because

Fig. 12—Operator using electrically operated wire wrapping pistol. All wires are precut to suitable length.

of the multitude of operations required. They can, however, be designed for economical die casting. One of the eleven such castings used in the system is illustrated in Fig. 13. In addition to reduced costs, the die castings offer a number of other advantages. Die castings are uniform in dimensions, facilitating assembly as well as aiding the interchangeability of the plug-in

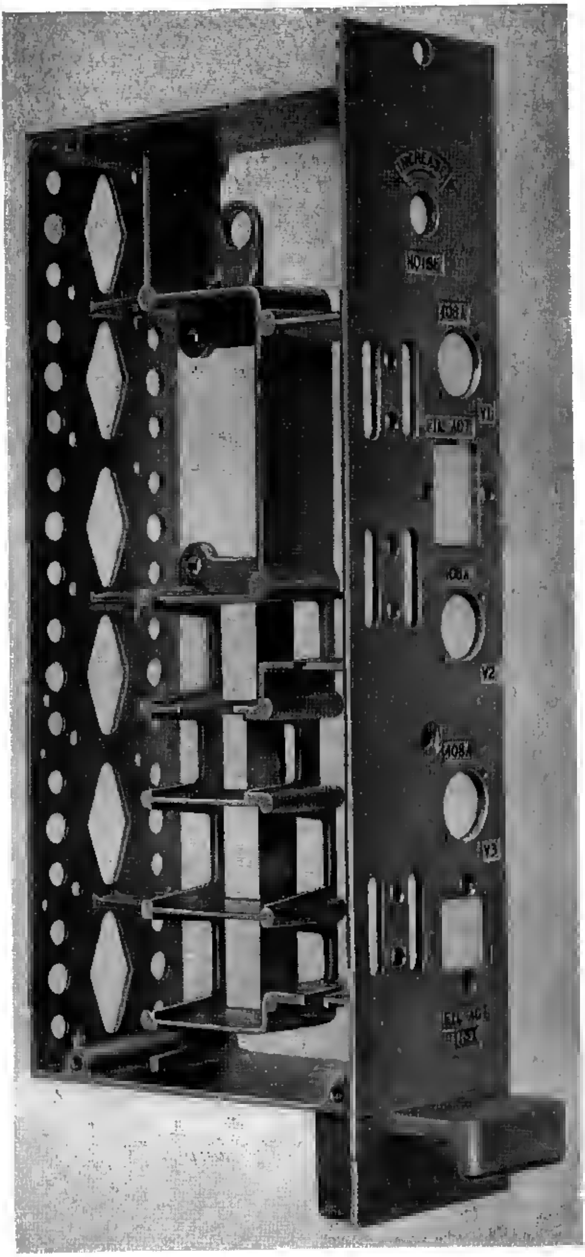

Fig. 13—Aluminum alloy die casting for the low group transmitting subassembly. On the front of the casting may be seen the equipment designations. The large number of holes in the rear surface provide clearance for filter terminals as well as filter mounting holes. In the middle portion of the casting are a number of pockets used to hold miniature transformers.

subassemblies and equipment units. The surfaces are reasonably smooth as cast and the natural aluminum finish is rather pleasing in appearance,

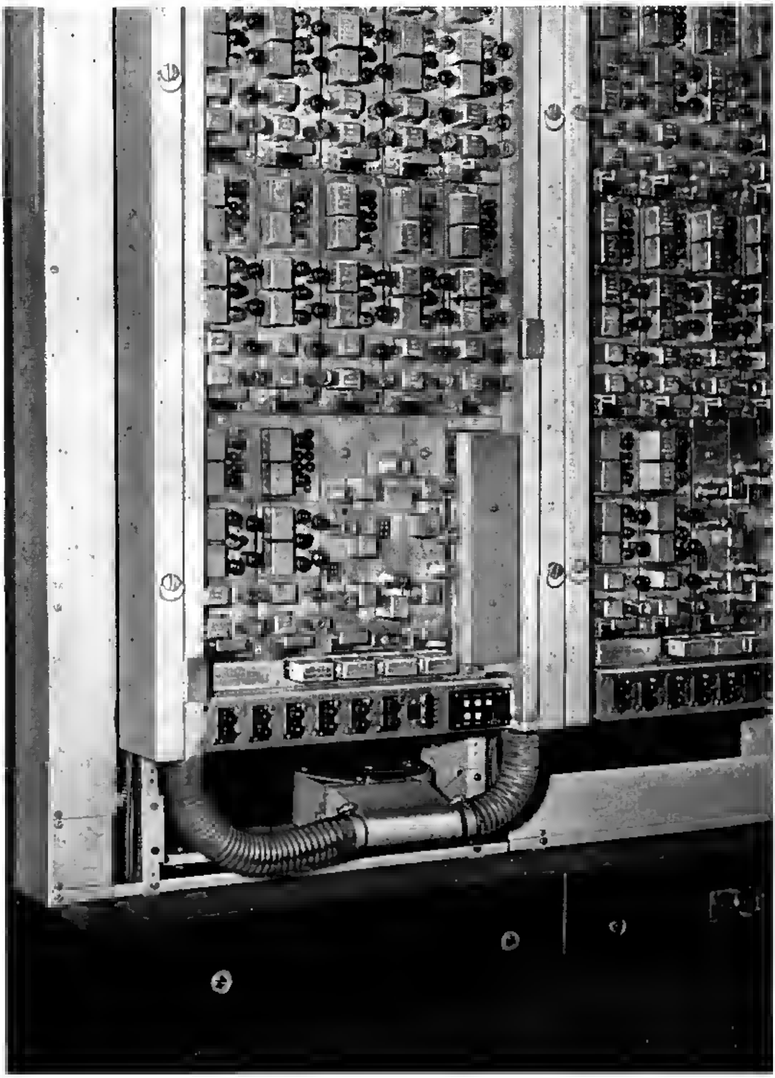

Fig. 14—Commercial installation of N-1 carrier terminal equipment showing one complete terminal. At the bottom of the relay rack may be seen an experimental model of a blower and associated air hose connections.

so that no further finishing operations are necessary. Equipment designations to identify components are incorporated in the die by the use of

raised characters in a recessed area, instead of being applied by stamping methods. The light weight of the aluminum die casting makes easier the handling of a plug-in unit, particularly when the maintenance man is working on a ladder.

Terminal Equipment

The terminal equipment as shown in Fig. 14 is designed for maximum flexibility and mounts in the relatively small rack space of 19 by 40 inches. Three such terminals can be mounted in a standard 11-foot 6-incb relay rack. A complete terminal includes 12 channel units, a transmitting group unit and a receiving group unit. These units plug into a terminal mounting fabricated of aluminum in natural finish, wbich is secured to the relay rack. The terminal mounting, shown in Fig. 15, consists of two side members of channel section witb metal sbelves welded between them to support the equipment units. The twelve channel units are mounted five in each of the two rows and two in the tbird row; the remainder of the bottom row is used for the group units and for alarms and miscellaneous apparatus. The terminal framework and wiring are the same for a terminal transmitting the high group or one transmitting the low group. The fuses and alarm relays for the terminal, and fuses and resistors for the power supplied to an adjacent repeater, are located at the bottom of the terminal mounting. Provision is made for mounting a span adjustment pad when required. Both at the terminals and at the repeater points the receiving lines are built out by these span adjustment pads so that the electrical length of all lines is the same. The wiring between the connectors for the channel units and for the group units runs within the shelf structure out to each side of the bay and tben extends up and down the mounting in the side members. Extra connectors are multipled with the group unit connectors to permit tbe replacement of these units without service interruption. All connectors are mounted so that tbe wiring and the soldered connections are readily inspected and maintained from the front of the relay rack, permitting back-to-back mounting or mounting against a wall. All external wiring is brought to terminal strips located at the bottom of the mounting.

Channel Units

Each channel unit contains the apparatus, including that required for signaling, associated with one channel. The units for channels 1 to 12 differ only in the receiving filter and in the crystal unit which determines tbe channel carrier frequency.

The apparatus is mounted in three subassembly frameworks which are fastened together to form one unit, as shown in Fig. 16. The subassemblies, shown in Fig. 17, are (1) the compressor (voice-frequency transmitting)

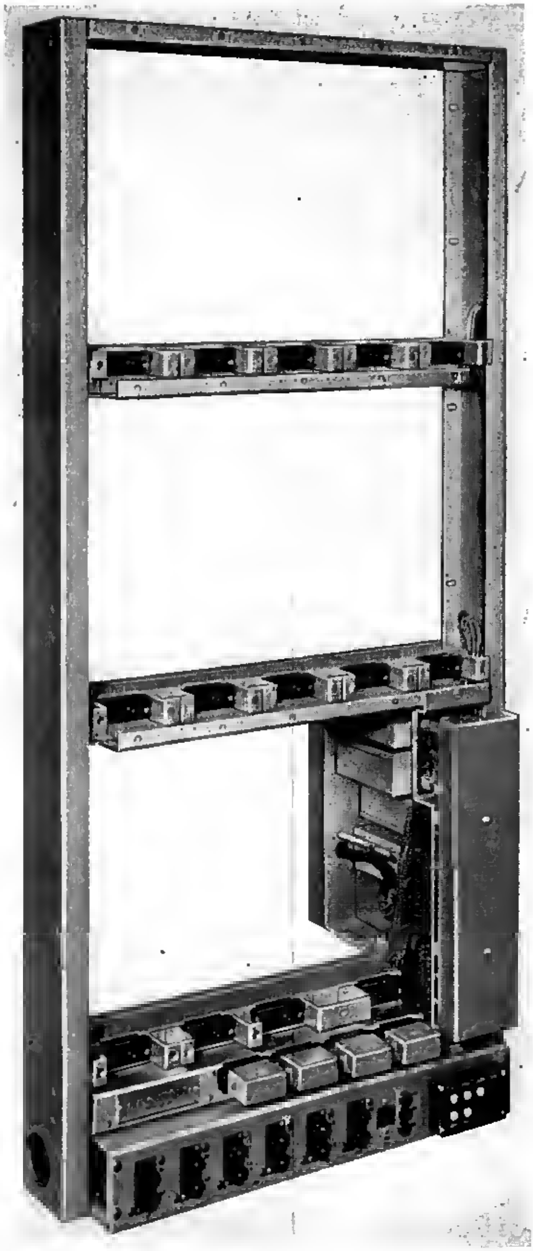

Fig. 15—N-1 carrier terminal mounting without any of the plug-in units. The shelf structures, including the fuse mounting at the bottom, are so arranged that they may be turned over to expose the wiring side of the connectors.

Fig. 16—Channel unit—front view. The unit is equipped with a perforated aluminum can cover.

subassembly; (2) the expandor and signaling (voice frequency receiving) subassembly; and (3) the carrier frequency subassembly. Provision is made in the carrier frequency subassembly for automatic channel transmission regulation. Subassemblies (1) and (2) are identical for all channels. An exploded view of the expandor and signaling subassembly is shown in Fig. 18.

Terminal Transmitting and Receiving Group Units

The transmitting and receiving group units together contain the transmitting and receiving amplifiers; the group modulator, which is used in either the transmitting or receiving branch but not in both; the signaling oscillator; and the carrier alarm circuit. Provision is made for automatic group

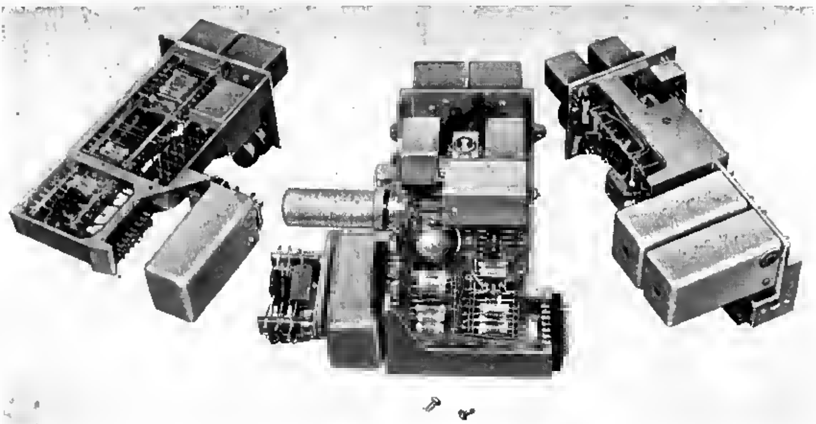

Fig. 17—Channel unit subassemblies. Compressor at left; expandor and signaling at center; carrier at right.

transmission regulation in the receiving circuit. There are four types of group units: one high group transmitting, HGT, and one low group receiving, LGR, for a terminal which transmits the high group of frequencies and receives the low group; and one low group transmitting, LGT, and one high group receiving, HGR, for the reverse terminal.

The group units are combinations of three of the following subassemblies as required: (1) high group transmitting, (2) low group transmitting, (3) high group receiving, (4) low group receiving and (5) oscillator. The oscillator subassembly supplies the group carrier frequency and the 3700 cycle signaling tone. The oscillator subassembly is plugged into a low group transmitting or a low group receiving subassembly and the combination equipped with a common can cover to form an LGT or an LGR unit. The addition of a cover to the high group transmitting or high group receiving subassemblies forms a complete HGT or HGR unit.

Terminal Temperature Control Equipment

Due to the compactness of assembly achieved with the cubic method of mounting there remains very little free space for natural or convective cooling, and excessive concentration of heat may be expected. For the N-1 carrier terminals it was found necessary in high temperature areas to provide forced air cooling. Although the major power dissipation occurs in the vacuum tubes, which are mounted on the face of the units, considerable heat from this source is conducted through to the inside of the units.

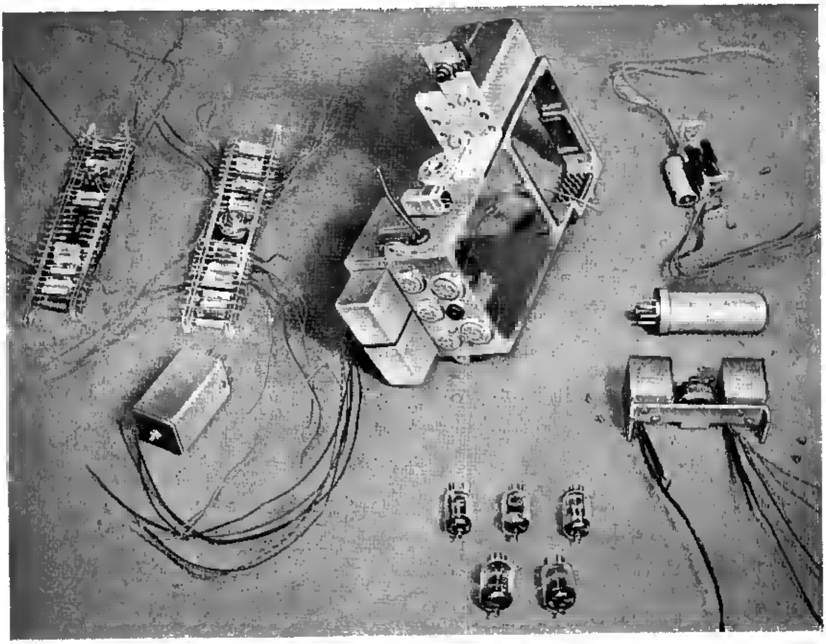

Fig. 18—An exploded view of the expandor and signaling subassembly ready for the final assembly operation. This shows the extent to which prewiring of small assemblies is used.

With a power input of approximately 400 watts per terminal serious damage to some of the apparatus might result if forced cooling were not provided in those offices where summer temperatures are high. With forced cooling the maximum temperature rise is reduced to a limit well within the capabilities of the apparatus used.

The temperature control equipment consists of a centrifugal blower driven by a $\frac{1}{12}$ HP 115 volt a-c motor which circulates air through ducts to the equipment. The motor and blower are mounted at the bottom of each relay rack with flexible connections to rectangular aluminum ducts extending up

along the faces of the terminal mounting framework uprights. Each duct has an aperture opposite each horizontal row of equipment units. A thermostat located in one of the terminal mountings starts the blower when cooling is required.

Repeater Units

Two types of carrier repeater equipment units are used in the N-1 system. They are identified by the designations HL (high-low) and LH (low-high). The HL repeater receives signals at high group frequencies from the line, translates them by modulation with a suitable carrier to low group frequencies, then amplifies and regulates them for transmission at the desired output level. The LH repeater functions similarly except it receives low group frequencies and transmits high group frequencies. Each repeater provides for transmission in both directions and the two types are used alternately along the line.

A repeater equipment unit is made up of three subassemblies. In the HL unit a right-hand high-to-low repeater and modulator subassembly for east-to-west transmission and a left-hand similar subassembly for west-to-east transmission are plugged into a common subassembly which supplies the carrier for group modulation and the voltage regulator, all under a common can cover. In the LH unit the right-hand and left-hand subassemblies are similar to those in the HL unit except low-to-high instead of high-to-low. The common oscillator subassembly is identical in all repeaters.

Repeater Mounting Arrangements

Each repeater unit is plugged into a repeater mounting bracket which is a small die casting equipped with three multipled connectors, one into which the repeater is plugged and two for testing and in-service replacement of the repeater. A terminal strip for external wiring connections, and span adjustment pads, when required, are also mounted on this bracket. Four of these mounting brackets are fastened to a shelf structure arranged for relay rack mounting. With the four repeaters plugged in place, the entire assembly occupies a vertical space of approximately 14 inches. The four-repeater groups so constituted may be located in pole-mounted cabinets at non-power supply points or on relay racks with associated power distribution panels at power supply stations.

A total of twelve repeaters can be accommodated in a pole-mounted cabinet, as shown in Fig. 19, together with order wire equipment and a 52-pair cable terminal. The terminal is located at the top of the cabinet when the toll or exchange cable is aerial and at the bottom of the cabinet when the cable is buried. The cabinet is made of sheet steel with the outside walls finished in white enamel to keep heat absorption to a minimum.

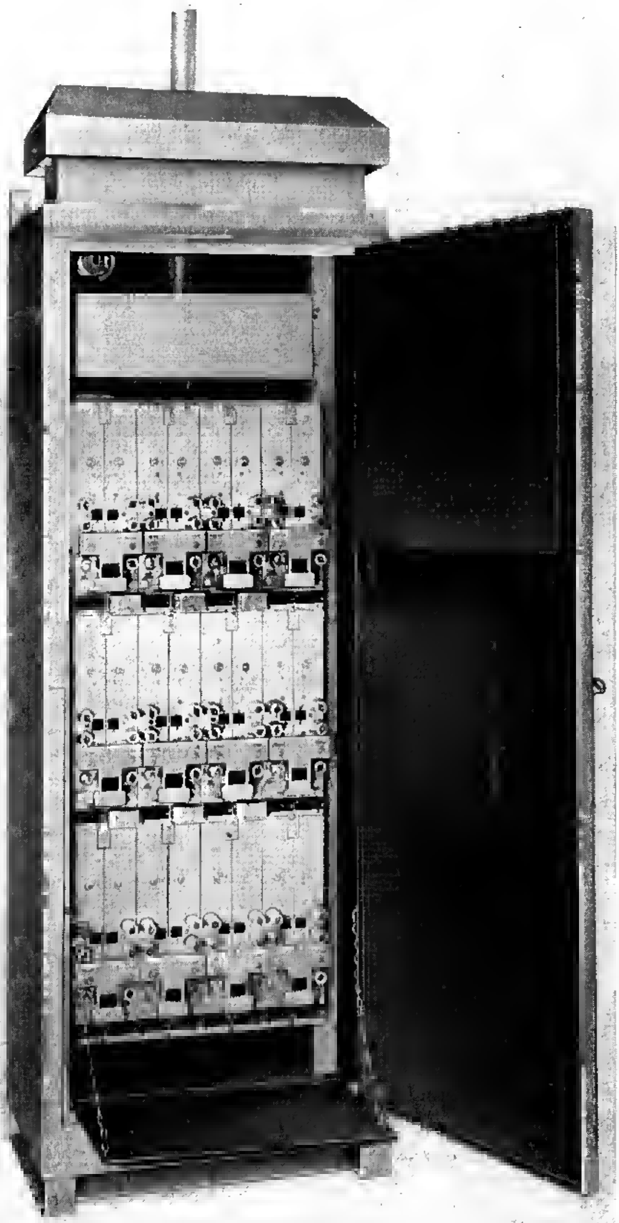

Fig. 19—Pole-mounted cabinet with 12 repeaters and cable terminal in position for aerial cable.

Thermal insulation and a thermostatically controlled vent damper limit the temperature range inside the cabinet to approximately 0°F to +150°F for an outside temperature range of −30°F to +120°F. The temperature range within the cabinet would otherwise exceed that at which it is practicable to operate apparatus components and insure good performance. This type of temperature control is necessary since power is not available for operating either a blower or a heater.

At a power supply point, a power distribution panel is required for each four systems. This power distribution panel contains the power resistors, fuses and fuse alarm circuits for four local repeaters and four adjacent repeaters in each direction. Other equipment that may be furnished in such an office on a miscellaneous basis is the deviation equalizer panel and the artificial lines required to build out very short spans. The relay rack layouts may be arranged in a number of ways to suit the particular installation since no shop wired bays are used. The installation effort is minor since very little wiring is involved. A typical 11-foot 6-inch relay rack layout at a power supply point will provide for 16 repeaters including some space allowance for miscellaneous equipment.

Testing and Maintenance Features

Potentiometer controls and test terminals are furnished in the various plug-in units for line-up and trouble localizing purposes. In the case of a channel unit, certain adjustments and tests may be made without removing the unit from its frame mounting while others can be made only following the removal of this unit. If removal is required, a multi-conductor test cord provides the means for reconnecting the removed unit to its connector in the frame mounting thereby providing access to test terminals and controls within the unit. Also at the terminal office, a portable group unit switching set permits substitution of an alternate transmitting or receiving group unit for the regular group unit without interrupting service. When the removal of a repeater is necessary, it is similarly accomplished without service interruption by the use of a portable repeater switching set. Both switching sets facilitate tube replacement. Two portable tube test sets have been designed for inservice testing of cathode activity of tubes in repeater and group units. An additional repeater test set is used in system line-up and maintenance adjustments.

A portable maintenance center test set has been designed for use with N-1 carrier equipment. This set is capable of testing and adjusting all equipment units, and the two portable switching sets. The test set is essentially a device for interconnecting oscillators, measuring equipment and the units to be tested. Filters and attenuators are included for controlling test currents.

Power Supply

The power supplies required for the N-1 system may be obtained from standard office signaling or telegraph power plants without additional filtering. The terminal equipment requires −48 volt and +130 volt supplies. Repeaters located at power supply points require +130 volt power only. For feeding power over the line to distant repeaters +130 volt and −130 volt supplies are used in combination as a 260 volt source.

Alarms and Order Wire Equipment

Each system terminal makes provision for the following alarms which are connected to the standard office alarm system:

a. Fuse alarms for all battery supplies.

b. 3700 cycle signal oscillator failure alarm.

c. Alarm which indicates failure to receive carrier at terminals.

The equipment for these alarm circuits is assembled as part of the terminal mounting with all wiring accessible from the front of the relay rack. Similarly at the repeater point where power is locally supplied the associated power distribution panel is equipped with fuse alarm circuits for the battery supplies.

No alarms are provided at or from non-power supply repeater points. Alarms from an unattended or partially attended repeater office can be extended to a fully attended office, when desired, over one pair of a quad in the cable which has its side circuit equipped with H88 or H172 loading. The other pair of this quad may be used as an order wire for system maintenance. The simplex legs of the two pairs are used to transmit power from power supply points to the portable repeater switching set used at pole-mounted repeaters. The equipment arrangement for the order wire and alarm circuits makes use of the conventional panel method of mounting and provides for a variety of layouts to fit particular applications. Amplifiers are introduced into the order wire and alarm circuits at terminals and power supply repeater points as required. At pole mounted repeaters the order wire equipment consists only of a pair of binding posts for connecting a lineman's test set.